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VALLEY DEPENDENCIES OF THE SCIOTO ILLINOIAN LOBE IN LICKING COUNTY, OHIO.[1]

FRANK CARNEY.

Leverett classifies the drift of eastern Licking County as Illinoian. He says: The Illinoian deposits are much heavier in valleys than on uplands, and there is a marked sinuosity of margin to conform to the topographic conditions.[2] The observations described in this paper were undertaken in part to give closer definition to the extent of the topographic control to which Leverett refers. The paper attempts to show that the Scioto lobe on this part of its eastern margin, where it reached out over the more rugged topography of the coarser Mississippian and Pennsylvanian formations, was affected by valley dependencies. It is felt that a detailed study of the marginal areas may add to our knowledge of the exact shape of the ice-front at the time of its maximum extension.

MARGIN OF THE ILLINOIAN DRIFT.

In central Ohio.—The general location of the Illinoian sheet, according to Leverett,[3] reflects the influence of great basins in the topography farther north, the Huron-Erie basin probably controlling its extension into the tract now drained by the Scioto River. That the extreme reach of the Illinoian ice in the southern part of the state—i. e., where it crosses the Ohio River in Brown County—is due to a combination of controls, seems likely.

Fig. 1 gives the results of Leverett's mapping of the Illinoian ice in Ohio. It appears that in one general locality on the eastern side of the Scioto lowland the ice manifested a tendency to protrude, as is shown by the curve southwest of Muskingum County; another evidence of this impulse is seen (Fig. 2), just north of this convexity, in the valley dependencies reaching beyond the body of the ice-field, described in the present paper. This later

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[1] Reprinted from the *Journal of Geology*, Vol. XV, No. 5, July-August, 1907.

[2] *Glacial Formations of the Erie and Ohio Basins;* XLI Monograph, U. S. Geological Survey (1902), p. 222.

[3] *Ibid.*, p. 226.

and more leisurely field-study gives greater prominence and exactness to this curve of local lobation first examined by Leverett.

In Licking County.—Save in the valleys, the Illinoian drift near its front is so attenuated that mapping it is a problem of elimination, or the careful study of the rather maturely dissected divide areas. The lesser details of topography in the marginal zone appear to have had slight influence on the outline of the ice-front, while obviously exercising a considerable control over the duration of the ice in its position of maximum reach. This latter fact necessitates patient observation, particularly where the stratigraphy did not encourage differential-weathering effects previous to glaciation; it is evident that on slopes of heterogeneous rock structure facing the direction of ice-movement, benches of the more resistant formations, weathered into semi-detached spires and blocks,[1] would have suffered some from ice-work, even though the products of residual decay did not receive a noticeable admixture of glacial drift. But among the hills, where the rock structure is more uniform, and the weathered slopes correspondingly even, the absence of foreign material must be established before drawing the drift-line; and in these higher areas an unexpected localization of erratics surrounded completely by territory in which the most diligent search has not revealed any evidence of glaciation is somewhat puzzling, but very convincing of the fact that the final demarkation of the glacial boundary is a problem of time.

In establishing the relationship of these valley dependencies of the Illinoian ice-sheet to the Scioto lobe, and in determining whether they are tongue-like extensions of the ice-mass at its period of greatest development, or at a later retreatal stage, three townships, Perry, Hanover, and Mary Ann, of Licking County, have been carefully studied, while like attention has been given to portions of adjacent townships. In valleys trending in general with the direction of ice-movement, the problem is one of distinguishing the unmodified drift from the deposits of entirely extra-glacial waters, and of determining the drift-covered portion of the valley walls.

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[1] F. Carney, *Bulletins of Denison University*, Vol. XIII (1906), p. 124.

It has been established that ice did not enter Perry township (Fig. 2) from the north or west,[1] and that the township was not glaciated save for the presence of a lateral tongue reaching northward from the valley lobe that extended eastward into Muskingum County (Fig. 3).[2] Less than one-half of the next township west, Mary Ann, was covered by ice; this ice had a very irregular front. The conspicuous drift knolls at Wilkins Run are alluded to by Wright,[3] and by Leverett.[4] One of the most typical valley trains of this region was built into the mature valley southwest of Wilkins Run.

The southeast corner of Eden Township was not glaciated; but the front of the ice has not been traced in detail through this township, nor into Fallsburg. A small portion of the northeast corner of Madison Township was not covered by ice. The outline of the drift in Hanover Township is considered in the following section. Southward into Hopewell Township the margin of the ice has been traced in detail for only a short distance.

VALLEY DEPENDENCIES.

At Wilkins Run.—A tongue of ice about one and seven-tenths miles long reached eastward from Wilkins Run. This village lies at one side of a mature valley which once embraced in its drainage the area east and north, the region now constituting the headwaters of the Rocky Fork; this defunct valley opened westward

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[1] F. Carney, *loc. cit.*, p. 124.

[2] Since the government has not issued a map of this area, the writer, appreciating the difficulty that one not acquainted with the region would have in visualizing the topography described in the paper, has attempted to represent in contours the relief of the section about Hanover. No traverse work was done; county surveyor's maps were used for the highways and horizontal distances, an attempt being made to correct the grosser errors. It is felt, however, that the altitudes in reference to the arbitrary bench mark selected have been established with greater accuracy. For this purpose two aneroids were used; these instruments are of the same make, and for over a year have shown the same variation when together. During the progress of the fieldwork the aneroids were set the same at the bench each morning; the one kept at the bench was read every thirty minutes. The time at which readings were made on the other instrument in the field was recorded; the watches were also set alike each morning. At night the field readings were corrected for the variations shown by the bench aneroid. Many critical points were checked several times.

[3] *The Glacial Boundary of Ohio,* Geological Survey of Ohio, Vol. V (1884), p. 755.

[4] *Loc. cit.*, p. 260.

into the valley of the North Fork of the Licking River, and belonged to the ancient Newark River.[1]

This tongue-like extension of the ice pushed eastward to the point where the valley turns to the north; a tributary from the east which joins the major at its bend to the north, being in line with the feeding ice, was blocked also. The ice reached northward but a short distance beyond this angle; a few drift knolls mark this brief position. A halt of considerable duration was made after the ice had retreated to a position bringing the north side of the valley tongue directly across the valley; here it built a marginal ridge averaging 90 to 95 feet high, at no point lower than 70 feet, and about 500 feet broad at the base (Fig. 4). A terrace of similar development marks the outline of the ice against the walls of the valley elsewhere, except in front of the tributary valley, mentioned above, through which most of the drainage from the ice was led east to the Rocky Fork valley. It is evident that the Rocky Fork drainage had gained control of the mature valley long previous to its being occupied by this ice.

These moraine terraces, best developed on the south side of the valley, are very conspicuous. Commencing across the valley from the hills mentioned by Wright,[2] a terrace of the aggradation type reaches half-way up the valley wall; it gradually descends eastward, where it becomes more irregular both because of initial distribution and of subsequent weathering. The line of demarkation between this drift and the upward slope is sharp.

The main body of ice, while the tongue reached eastward, maintained a position nearly north-south for a few miles each way from Wilkins Run. North of this place, so far as Mary Ann Township is concerned, the retreat of the ice-front appears to have been rapid, and there is no evidence that the valley lobe maintained intermediate positions; but the old valley becoming broader southwest of Wilkins Run encouraged a tongue-like extension of ice at the next halt of the ice-field; the well-developed valley train already mentioned was formed at this time.

At Hanover.—Here we have a much wider valley than the case

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[1] W. G. Tight, *Professional Paper No. 13*, U. S. Geological Survey (1903), p. 18.

[2] *Loc. cit.*, p. 755.

just cited. The tongue of the ice reached about six miles eastward from the main body of ice. The maximum position of this valley dependency is marked by typical morainic topography (Fig. 5), with a contemporaneous deposition of drift against the side walls of the valley, which above the glacial débris are veneered with rock decay *in situ.* The line of demarkation between this drift and the valley wall is shown very conspicuously on the Hagerty farm southeast of the 216-foot well (Fig. 3). The drift, judged from surface appearance, especially east of the Muskingum County line, is rather bowldry; no very large bowlders were noted, but their fewness may be accounted for by the fact that the area has long been under cultivation.

This tongue-like extension of the ice maintained its distal position for some time, but in comparison with the duration of retreatal positions the period was proportionately brief. At the second halt the alignment of the drift suggests a tapering of the ice-tongue; this form, however, is not seen in the other halts (Fig. 3, *H.* 3, 4, etc.), because of the contraction that exists in the valley in the vicinity of Hanover. So long as the ice fed actively through this narrow part it broadened some in the wider segment of the valley beyond; only in this latter area should we expect to find evidence of tapering as the ice-movement weakened.

Moreover, it should be noted that the distribution of the drift in this valley does not conform to the pattern usually normal to valleys[1] which encourage tongue-like extensions from the ice border in line with the direction of the deploying ice. The east-west valley passing Hanover is unusual in that it has a composite history, the most obvious feature of which, that it was formerly the course of a west-flowing stream, has been published.[2] The continuity of the south wall of the valley is broken by gaps at *A, B,* and *C* (Fig. 3), representing a change in the drainage-control of the region; the presence of these openings allowed free drainage, particularly in the case of *A* and *C,* from the southern side of the ice-tongue, thus removing much glacial rubbish that otherwise would have remained as a lateral terrace or ridge.

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[1] R. S. Tarr, *Bulletins of the Geological Society of America,* Vol. XVI (1905), pp. 218, 219.

[2] F. Leverett, *loc. cit.,* p. 155; W. G. Tight, *Bulletins of Denison University,* Vol. VIII (1894), p 47.

Furthermore, westward from Hanover the valley grows broader; at Newark, a distance of seven miles, it is about two miles between the rock walls. Consequently as the margin of the eastern side of the Scioto lobe assumed new positions in its decline—a long halt has been noted in the vicinity of Newark[1]—this valley dependency persisted.

The details of the drift south and southwest of Claylick have been studied for two miles, showing that the retreat of the main body of the ice was gradual, and apparently maintaining positions parallel to the convex margin mapped by Leverett.

SUMMARY.

A study of the Illinoian drift in this broken topography of the coarser-textured and more resistant formations of the Mississippian and Pennsylvanian periods establishes the existence of tongue-like dependencies of the Scioto lobe reaching out into the eastward trending valleys.

Geological Department, Denison University, Granville, O., April, 1906.

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[1] F. Leverett, *loc. cit.*, Plate II.

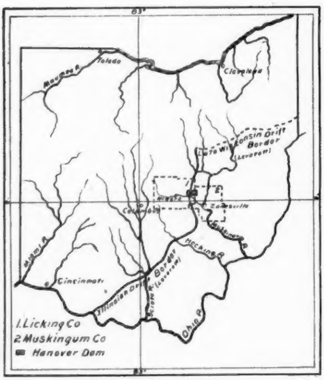


Fig. 1

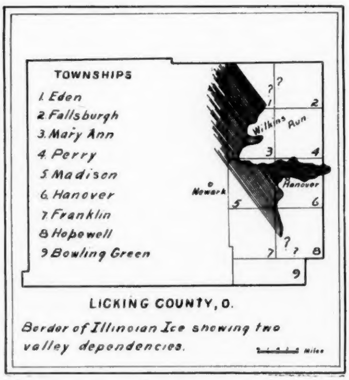
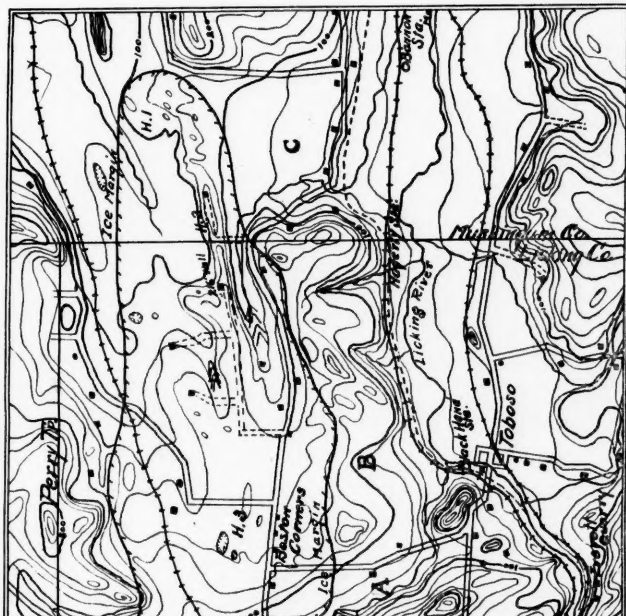


Fig 2

Topography of Hanover Dam Area



Contour interval 20 feet—Datum is arbitrary Bench Mark at M.
>>> Ice front channels — Fig. 5

Fig. 4. Looking south of west. The wooded area on the extreme left is rock, as is also the slope above the buildings on the right. The intervening ridge of drift marks the position of the ice-tongue that extended eastward from Wilkins Run.

Fig. 5. Moraine which marks the terminus of the Hanover valley dependency.

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THE GLACIAL DAM AT HANOVER, OHIO.

FRANK CARNEY.

THESIS: The glacial dam at Hanover consists of peculiarly tied-together drift loops made by successive halts of a retreating dependency of the Scioto Illinoian lobe.

INTRODUCTION.

Leverett calls attention to the mass of drift which blocks the east-west valley at Hanover.[1] Other writers in discussing drainage features have alluded to the same phenomenon.[2] Wright does not include this part of Licking County within the drift.[3] Leverett's map (Fig. 1) includes within the drift all the county save a narrow strip, convex towards the ice, along its eastern side.[4]

STRATIGRAPHY.

In this area the Missippian and Pennsylvanian formations from the Cuyahoga to the Sharon of the Pottsville are exposed. The lowest of these formations has been noted in but two localities. In the region under discussion the Black Hand formation was first studied, and named, by Hicks.[5] In east-west extension from Claylick to Toboso, and northward at least through Perry Township,[6] this formation is prevailingly coarse, often conglomeritic; westward about Newark[7] and Granville it is rather coarse in

[1] Frank Leverett, *"Glacial Formations of the Erie and Ohio Basins,"* XLI Monograph, U. S. Geological Survey (1902), pp. 155, 260, 286.

[2] W. G. Tight, *Bull. Sci. Lab. Denison Univ.*, Vol. VIII (1894), pp. 35-63. W. B. Clark, *Ibid.*, vol. XII (1902), pp. 1-16.

[3] G. F. Wright, "The Glacial Boundary in Ohio," *Geolog. Survey of Ohio*, Vol. V (1884), p. 755.

[4] *Loc. cit.*, plate XIII.

[5] L. E. Hicks, *Am. Journal of Science*, 3d Series, Vol. XVI (1878), pp. 216-217.

[6] F. Carney, "The Geology of Perry Township," *Bull. Sci. Lab. Denison University*, Vol. XIII (1906), p. 120.

[7] C. S. Prosser, *American Geologist*, Vol. XXXIV (1904), p. 359.

patches, and sometimes has conglomerate beds of considerable horizontal extension, yet it does not represent as constant conditions of sedimentation. Consequently in the Hanover area, the topographic control exercised by the Black Hand formation is very important.

The development of the Logan in this region is normal. Professor Prosser has studied an exposure, which is typical, at the Brick Plant (Fig. 3).[1] This formation disintegrates evenly, giving gentle slopes.

No outcrop of Maxville limestone was found, nor was this formation noted in the 25 square miles immediately north of Hanover Township.[2]

The Sharon conglomerate caps nearly every hill reaching an altitude of about 225 feet above the bench mark (Fig. 3). Much diversity in its structure is noted; to this condition is due the fact that we find in close proximity hills that vary 20 to 40 feet in altitude; the regular extension of drainage disintegration would not account for this discrepancy.

With the above arrangement of rock horizons: a conglomerate (Sharon, 250-feet) underlain by thin bedded sandy and shaly layers (Logan, 115-feet) capping a conglomerate (Black Hand, 100-feet) which in turn overlies a shale formation (Cuyahoga), we have a vertical succession that responds irregularly to stream erosion. Furthermore with the horizontal variations characteristic of the two coarse formations we find in the stratigraphy of the Hanover area another factor that has been active in producing its rather unusual rock topography.

PECULIARITIES OF DISSECTION.

The widest and apparently the oldest valley of this section is the one now blocked across by the Hanover Dam. This valley is explained as a "preglacial" west-flowing[3] drainage line, named

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[1] C. S. Prosser, *Journal of Geology*, Vol. IX (1901), pp. 230-231.

[2] F. Carney, *loc. cit.*, p. 122.

[3] F. Leverett, *loc. cit.*, p. 155.
W. G. Tight, *loc. cit.*, p. 47.

"Newark River."[1] The proximity of the two spurs, one from either side of the valley, just east of the Hanover Brick Plant (Fig. 3), and the fact that westward toward Newark and eastward toward Dresden the valley grows uniformly wider, suggests that at some anterior "preglacial" time two streams here headed against each other, the west-flowing one of the pair capturing the other.

This old drainage line controls from the north two tributary valleys, one of which now carries the Rocky Fork, the other being filled for some distance northward by the same drift material that bars the major valley. This latter valley is more mature in general aspect; it now bears a stream to the northeast, probably in reversed course. The Rocky Fork has a drainage basin extending about 15 miles to the north; during the recession of the ice sheet it carried an abnormal amount of water, the work of which is now seen in the terraces of water-laid drift that skirt its course.

From Toboso eastward is a valley whose maturity is strikingly in contrast with the stream it now bears. The aggraded glacial outwash materials that level up the floor of this valley, which widens to the east, have been terraced by the swinging meanders of a stream whose volume is likewise out of harmony with the Licking River which joins the Muskingum at Zanesville.

West from Toboso for two miles the Licking traverses a rock-walled gorge which abruptly expands south of Hanover into a wide valley that heads about two miles farther south. This valley is an arm of the old drainage line already described, passing Hanover westward through Newark.

Connecting these two east-west lines of dissection are four gaps in the rock divide. Three of these gaps cut through or into the Black Hand formation. The village of Hanover lies in the most western; the other three are designated on the topographic map (Fig. 3) by the letters, A, B and C.

The Hanover gap is Y-shaped, one branch extending toward the Brick Plant, the other being traversed by the Rocky Fork.

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[1] W. G. Tight, *Professional Paper No. 13*, U. S. Geological Survey (1903), p. 18.

Gap A is now the valley of a slight stream which rises in Perry Township. This creek is rock bound at a point just southwest of Boston Corners where the ice so abutted the nose of a spur that the drainage was forced across it thus cutting a channel which has held the stream since. From this point southward almost to its intersection with the highway, the creek skirts the conglomerate cliffs of the Black Hand. Throughout most of its course, however, the washings from the ice front have obscured the lower contours of the valley represented by A.

The next gap, B, is not so pronounced in its rock topography as the two cases just described. The hills immediately east and west (Fig. 6) are rock; the area intervening, and to the north, is buried with drift. Even with a moderate thickness of drift—a well at Boston Corners shows 50 feet and no rock—it is obvious that the rock rim of the divide dropping into the filled valley north is very much lower than the row of rock hills which the ice-margin skirts eastward. B then marks a gap of the same kind but not of the same degree as the others.

Fig. 6. Looking a little north of east from the top of the west wall of gap *A*. The curve in the traction line is in front of the southern end of gap *B*. The stream of *A* now enters *B* through a rock channel at foot of the wooded slope in right foreground; the camera stands about 200 feet above this channel, hence the picture does not show the former course of this stream.

C is the widest and presumably the deepest of these gaps. It too is clogged with drift; when viewed from the moraine hills north, the washplain origin of this aggraded deposit is evident. Its southern margin, that is, its line of contact with the flood plain area of the Licking valley, is sharply terraced, thus establishing a neighboring base-level that has encouraged subaerial dissection; as a result the washplain is somewhat roughened by the work of streamlets. This gap, C, represents long-continued lateral planation work of some stream, probably south-flowing; its sides have mature slopes (Fig. 7); its aggraded bed has about the same level as has the outwash plain reaching eastward in the valley of the ancient Newark River.

DISTRIBUTION AND DESCRIPTION OF THE DRIFT.

The area within the broken line, "ice margin," (Fig. 3), includes the deposits of unmodified drift; within this area there is also much washed drift, while outside the line we find only water-laid deposits.

Modified drift is found in all the valleys enumerated under the preceding section of this paper. In portions of these valleys adjacent to the ice front, the drift is of the outwash-plain type.

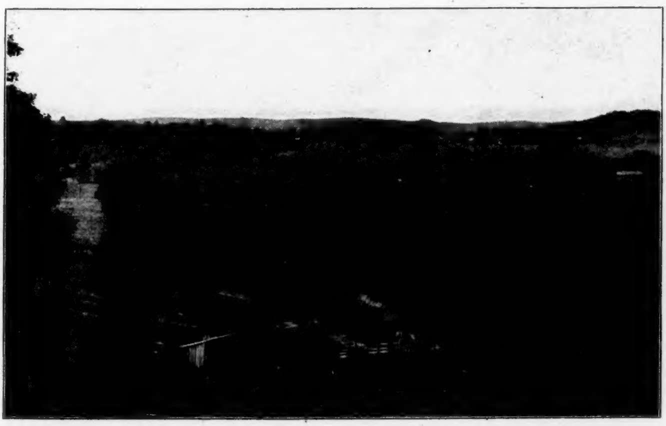

Fig. 7. Looking directly north through gap *C*. Camera stands on south wall of the Licking about 180 feet above the stream. The sky-line of the middle distance is the north wall of the old east-west (Newark) valley.

Elsewhere through these valleys it constitutes their flood plains so far as may be observed in the old terraces, in the erosion of the laterals crossing the flood plains, and in the notch made by the present major streams traversing them. The further distribution of washed drift in this part of the State has been described by Leverett.[1]

In topography the drift of this region presents some interesting features. Near the western edge of the area, just off the map (Fig. 3) in Madison Township, the moraine is quite kame-like. The low place now crossed by the Rocky Fork (Fig. 8) is due in

Fig. 8. Looking north of east over the inner slope of halt 5. The steep slope on the right is rock which lies within the Y-shaped gap at Hanover (p.141). The sky line is the north wall of the "Newark River" valley; the stream in the foreground is the Rocky Fork.

part to the removal of the drift by the augmented drainage from the ice-front north and west; this stream has terraced the drift east of the highway, thus possibly over-steepening the slope there, but the low sag is the result rather of rapid melting of the ice-tongue.

Proceeding eastward the highway rises about 100 feet, then crosses a level delta-like stretch of drift. The surface is mildly

[1] *Loc. cit.*, p. 157.

undulating, rarely having a vertical range of 20 feet. The surface material is rather fine, and as revealed in sections is sometimes water-laid; unassorted sections also appear. The highway leading north from the Brick Plant crosses four distinct channels (Fig. 9), which have neither the form nor the relative location of normal erosion channels; they are interpreted as made by ice-front streams. East of the highway, and about half the distance between the Brick Plant and the first road leading eastward, the drift assumes a sharp morainic aspect. The level-topped area west of the highway continues northward in the valley extending into Perry Township; here too the delta-like appearance blends into more irregular forms of the drift, suggesting intervals of retreating and stationary positions of the lateral tongue which fed into this side valley.

In eastward continuation we have next another interval of descending contours (Fig. 10), denoting a period during which the melting factor was greater than the ice-feeding factor. Here the Pennsylvania railroad swings northward towards the sag between the ice margin and the valley wall. In doing this the railroad has made a cut about one-half mile long and 50 feet in maximum depth. The great amount of clay in the drift has necessitated a wide cut and frequent cribbing. The region of this cut,

Fig. 9. View from the hill south of the Brick Plant looking northward. Most of the area shown is the flat-topped interval between halts 4 and 5. The middle distance shows this flat area extending into the tributary valley northward. The ice-front channels appear along the highway leading north.

while rather plain-like in surface, is contiguous to morainic topography.

From the vicinity of Boston Corners to the easternmost reach of the ice-tongue we have a recessional period of drift accumulation during which the ratio of the supply to the melting factor was a little less than unity; but in the neighborhood of the 216-foot well (Fig. 3) there is evidence of a stationary condition of the ice. Through this whole distance, kettles are quite common, some of which are designated on the topographic map. Extending eastward from this deep well there is a marked morainic ridge, for a ways simulating in its form an esker, but gradually broadening into the mass of very irregular drift in which the loop terminates (Fig. 5), reaching about one mile into Muskingum County where glacial drift *in situ* has not been previously reported.

To account for this ridge there are two suggestions: The ice-front drainage in the direction of Black Run, which lies just off the northeast corner of the map, may have been sufficiently vigorous to remove most of the débris collected from the melting ice; it will appear in later discussion that there was active drainage in this direction. Or the load of rubbish carried by this valley dependency may have been much greater on its southern side; the rock spur on either side of Hanover offered ample obstruction to the progress of the ice to encourage acquiring a load.

An analogous arrangement of rock spurs is noted on the opposite side of the valley; here, however, it is apparent that the tributary valleys were occupied by laterals from the ice-tongue, thus lessening its power of erosion. The low area in which Hanover lies was not similarly filled with ice for the reason that its approach from the north is an almost continuous wall of rock (Fig. 8), save where the Rocky Fork has incised it. This wall was doubtless considerably lowered by ice-erosion as there is but little Logan sandstone capping it, and apparently some of the Black Hand in places was also carried away. So it seems that the conditions for acquiring a greater load of rubbish were in favor of the south side of the tongue of ice that fed eastward through this valley.

Fig. 10. Looking west from halt 3. The leveled surface of halt 4 shows in the middle distance; camera stands on the west slope of halt 3. Barn on left is in line with the Brick Plant.

THE DELTA-LIKE TOPOGRAPHY OF PARTS OF THIS VALLEY DRIFT.

As one approaches the Hanover Dam area from Newark, he notes the strip of even sky-line, flanked by irregular horizons, blocking the valley (Fig. 8). In ascending the grade just east of the Rocky Fork, gravel is conspicuous in the road gutters. Having reached the summit, it is evident that "the top is nearly plane." [1] And looking eastward the second area of level topography, near Boston Corners, tends to emphasize the resemblance to a delta, or an outwash deposit "from the ice sheet into a body of water held in the valley to the east." [2] This second level strip averages 10 to 15 feet lower than the first, thus the dam "descends gradually eastward." [3] Therefore the topography and the surface materials suggest that "while the dam was accumulating a lake probably occupied the valley to the east."[4]

If this accumulation is outwash material, delta-like in form, then we would anticipate finding other but probably smaller deltas marking the mouths of valleys that were tributary to the area involved by the static body of water extending eastward. During the long interval since these smaller deltas, if any existed, were built they must have suffered much from erosion and solifluction,[5] but not to the extent of being obliterated. We have studied

[1] F. Leverett, *loc. cit.*, p. 260.
[2] *Ibid.*, p. 260.
[3] *Ibid.*, p. 260.
[4] *Ibid.*, p. 286.
[5] J. G. Anderson, *Journal of Geology*, Vol. XIV (1906), pp. 95-96.

many minor deltas laid down in ponded bodies which filled the short but wide tributaries of the major valleys, so common in these Mississippian-Pennsylvanian horizons, and have been surprised at the little disintegration such slight deposits of sediments have suffered. And the lapse of time since the Illinoian glaciation is perhaps greater than is generally supposed. But concerning the "smaller deltas" of the body of water in question: very diligent search shows that there are no such deltas.

Furthermore a detailed study of the boundaries of the Hanover Dam shows the improbability of a ponded body of water having been confined in the area, at least since long anterior to the earliest glaciation. Gaps, A, B, and C, as shown on the topographic map are low places in the rim of the basin that must have been involved in such a static body.

These gaps are tributary valleys of the drainage line now occupied by the Licking River. They have tended to keep consonant grade with the major valley; proof of this fact, however, is observed only in valley A, the stream of which now flows just east of the isolated rock hill at Black Hand station (Fig. 3); this stream has hardly yet attained the grade of the major stream (Fig. 6), with which it possibly at a former time made its junction just west of this isolated hill. This western outlet was maintained till some progress was made in disintegrating the Black Hand formation; then a tributary of the stream that was at work in valley B, because of variation in the structure of this formation, was led headward into valley A, and captured its drainage. This episode in the evolution of these gaps is mentioned for the purpose of emphasizing their chronology.

The slopes of the rock walls of valley C (Fig. 7), when plotted downward, give a depth for the bed rock quite in harmony with the record of the well-boring a short distance west of the line along which this valley blends into the east-west filled valley (Fig. 3). This well reaches a depth of about 150 feet below the general

altitude of the outwash materials now observed in valley C; the well does not get into rock.[1] Leverett suggests that the surface of the Hanover Dam may stand 300 feet above the rock floor of the old valley.[2] The width of gap C is measurable; its depth is obviously below the surface of the drift under discussion. That the rock-sculpturing here observed antedated the formation of the Hanover Dam seems very probable.

If the disintegrated rock removed from these gaps, A, B, C, were replaced, and a wall of ice were standing across the east-west valley at Hanover, we would then have, so far as this immediate area is concerned, the requisite conditions for an ice-front lake. But since such a lake would extend eastward, its level in no case, save that of a hypothetical differential tilting, could rise higher than the overflow that would be established at the first outlet reached; such an outlet exists about one mile east of the area shown on Fig. 3; it joins the valley of the Licking at Nashport, and is traversed by the old canal. It appears therefore that any one of the valleys, A, B, C, was fatal to the existence of the conjectured lake. But if these gaps were not developed till after the Illinoian ice-invasion, and if the other southward-extending drainage lines to the immediate east did not exist, then a body of water was held up in this old valley by the ice.

INTERPRETATION FROM THE STANDPOINT OF A VALLEY DEPENDENCY.

Many difficulties of this problem clear up when we understand that the ice reached into Muskingum County. Judging from the amount of drift here deposited, from its stony texture, and from

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[1] In a letter dated Nov. 27, 1905, Mr. G. E. Swigert says concerning this well: It is a drilled well. It is 216 feet 3 inches from top of casing. We went through 10 feet of yellow clay; 90 feet of blue clay, or better known among drillers as hard pan; and from there 114 feet of quick sand; thence to gravel and completed the well in the finest (best?) coarse gravel I ever saw. There is 131 feet of water in the well. We struck a small seep of water about 85 feet down. * * * We took out a few leaves and one or two walnuts from the quick sand about 150 feet down. * * * I never saw such mean stuff to work with; we would work all day, and get 2 or 3 feet.

Tight, *Bull. Sci. Lab. Denison Univ.*, Vol. VIII (1904), p. 44 and Plate IV in his map and in his description places a 218 foot well just north of the rock spur near the Brick Plant; again he speaks of it as "about one mile east of Hanover." There is no other deep well in this part of the county, so Tight must have been alluding to the Swigert well.

Leverett (*Loc. cit.*, p. 156) in discussing the old drainage quotes Tight's data concerning this well.

[2] *Loc. cit.*, p. 286.

its surface features, we infer that this most distal position of the ice was maintained for some time (Fig. 3). Another rather prolonged halt [1] in the retreat is apparent at and immediately west of the Swigert well. The depth of clay found in this well, and in the well of Mr. Felix Claypool at Boston Corners is also evidence of unmodified drift. Kettle holes, many of them not yet filled by vegetation, are common. The topography indicates another halt of the ice across the valley near Boston Corners; the fourth halt going west is in the section crossed by the road northward from the Brick Plant; the last halt concerned in this problem is marked by the slope just east of the Rocky Fork (Fig. 8), a slope which has been considerably deformed by later stream terracing.

The delta-like reaches of the Hanover Dam, it should be noted, lie in rock-walled segments of this old valley. The apparent exception in the position of gap, B, is not real, for the following reason: when the ice retreated from the northern end of this gap it left a ridge of drift; this was the retreat that followed halt 2. This ridge of drift fitting against the rock hills both northwest and northeast of the letter B, on Fig. 3, had the effect of a rock enclosure, exerting the same control as the rock slope east of Hanover. The withdrawal of the ice from position 2 to position 3 was gradual, leaving in its path a marked morainic topography. The retreat between halts 3 and 4 was more rapid (Fig. 10); while a much longer period of time was used, and a correspondingly greater drift accumulation was formed (Fig. 9), by the ice before making the last stand, halt 5.

It appears then that when the ice-tongue fronted at position 3 there extended eastward as far as position 2 a fairly static reach of water; this was an evanescent condition, but was of sufficient duration to partially level-up the hummocky surfaces with an assorted deposit varying in thickness.

We note the same combination of conditions again when the ice stood at position 5. But here the work was probably on a larger scale, because the normal ice-front drainage was greatly augmented by the accession of the waters of the Rocky Fork which was carrying the run-off of a valley dependency extending eastward from Wilkins Run (p. 133). Gap A for some time conducted

[1] These halts are indicated on the topographic map, Fig. 3, by 1, 2, etc.

these waters to the valley southward; the ice-front channels north of the Brick Plant (Fig. 9) were cut during the earlier stages of this halt.

Thus the two locations that favored slack water are marked by level areas; in spots this superficial material is gravel, elsewhere it resembles ordinary flood plain deposits.

ALTERNATE HYPOTHESES.

1. If gaps A, B and C are of post-glacial development, and if there were no cross valleys to the east lower than the top of the Hanover Dam, then a lake could have occupied the valley, provided further that the grade of the old east-west stream had not already been reversed. We feel that subaerial erosion even since Kansan-drift times is incompetent to accomplish the disintegration represented by these north-south gaps; only gap A ever carried much ice-front drainage, and since the cessation of this abnormal stream work, these gaps have controlled only slight drainage basins. In view of observations which the purposes of this paper do not warrant stating here the writer feels that this area was tributary to eastern drainage before the earliest ice invaded this part of the state.[1]

Such care has been taken in mapping the area, and in the description of the drainage lines, that it seems needless to point out the impossibility of this alternate hypothesis. It may be said in addition that the great amount of aggraded ice-stream deposits in the gaps B and C (Figs. 6 and 7), blending into the terraced floodplain of the Licking indicates that, before the ice had moved across or opposite their northern ends, these gaps existed in greater maturity than they now indicate. Furthermore if these gaps are post-glacial—even post-Wisconsin—in development, then at their up-stream terminals they should open into marked flat areas, since streams equal to removing the succession of rock formations already described should have carried off, incident to the lateral planation activity indicated by the width of the gaps, a much greater mass of glacial drift.

2. If there was a general subsidence of the land shortly after

[1] This interpretation is contrary to the findings of Leverett, *loc. cit.*, p. 155; and of Tight, *loc. cit.*, p. 47.

the maximum development of the ice which deposited this drift, then a lake may have existed here, but its area must have been greater than has been supposed.[1] In discussing the silts found in Ohio, Leverett says: That this region had an unfavorable altitude for drainage in the preceding Sangamon interglacial stage, and probably stood much lower than at present, seems evident from the shallowness of the valleys which were opened on the surface of the Illinoian drift. The drainage conditions seem to have become still more unfavorable during the silt deposition, so that erosion was either suspended or became so weak that it could not keep pace with deposition. This increased imperfection of drainage conditions seems best explained by a depression of the land.[2]

Assuming that this depression was well in progress when the Illinoian ice commenced to wane, it is possible then, with the ice front at halt 5 (Fig. 3), the depression of the land not attaining its maximum during this halt, that, as the level of the water gradually rose, the load from the ice was distributed by this water, developing the existing delta-like surfaces. Under this explanation it follows that the silt which is common over the surface of the Hanover Dam was deposited after the ice had further retreated. In any event, if connection is to be established between this possible silt-producing depression of the land and the origin of the Hanover Dam, no long period of time can intervene; the successive halts of the ice, after its farthest reach into Muskingum County, indicate appreciable time periods; the retreat following halt 5 terminated all connection of the ice with any such explanation of the origin of this mass of drift. It is necessary, however, before admitting even the feasibility of this hypothesis to recall that contemporaneously with the development of the Hanover Dam other deltas should have been in progress of formation, evidence of which is wanting.

With the establishment of certain prerequisite conditions either of these hypotheses is sufficient to account for this delta-like accumulation. But this drift dam is so morainic locally in surface

[1] Leverett, *loc. cit.*, p. 286.

[2] *Loc. cit.*, p. 301.

features, and contains so much till, that its two level areas, which indeed simulate true deltas, must be regarded as the result of an unusual slack-water condition of immediately ice-front drainage.

SUMMARY.

1. The ice-front in eastern Licking County was characterized by valley dependencies. Further work will doubtless show a fringe of valley dependencies wherever the lobes of the ice sheets reached into the rough topography, resulting from the weathering of the Mississippian and Pennsylvanian formations.

2. The Hanover Dam is the product of one such valley dependency.

3. The amount of disintegration accomplished by all weathering agents since the invasion of the Illinoian ice sheet may easily be overestimated.

4. The principles of sedimentation illustrated by the above formations furnish suggestions in deciphering the erosion history of this part of Ohio.

Geological Department, Denison University, Granville, Ohio, March, 1907.

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THE ORIGIN OF SPRING VALLEY GORGE.[1]

EARL R. SCHEFFEL.

OUTLINE.

INTRODUCTION.

The area considered in this article is the Old Valley lying approximately southwest of Granville, Licking County, Ohio, a valley about one mile wide at its junction with the valley of the Raccoon to which it is tributary, with a longitudinal axis trending southward nearly one and one-half miles. Fig 2 shows a general view looking from the high knob on the west (marked in Fig. 1, 156 ft.) toward the east.

Among the features of this Old Valley attention is particularly called to the main drainage line following, contrary to general drainage laws, a course neither the longitudinal axis nor tributary to this axis, but parallel to it, flowing for a part of its course laterally on the east valley wall in a rock channel. This rock walled incision is locally known as Spring Valley and is so designated in this paper.

The purpose of this investigation is to determine the Geologic time and genesis of this stream, particularly with reference to the Spring Valley (between *X* and *X*, Fig. 1 and Fig. 2) part of its course. For purposes of proof, it is requisite that not only Spring Valley should be studied, but also its tributary streams, as well as

[1] This work was performed under the direction of Professor Frank Carney as partial requirement for the Master's degree.

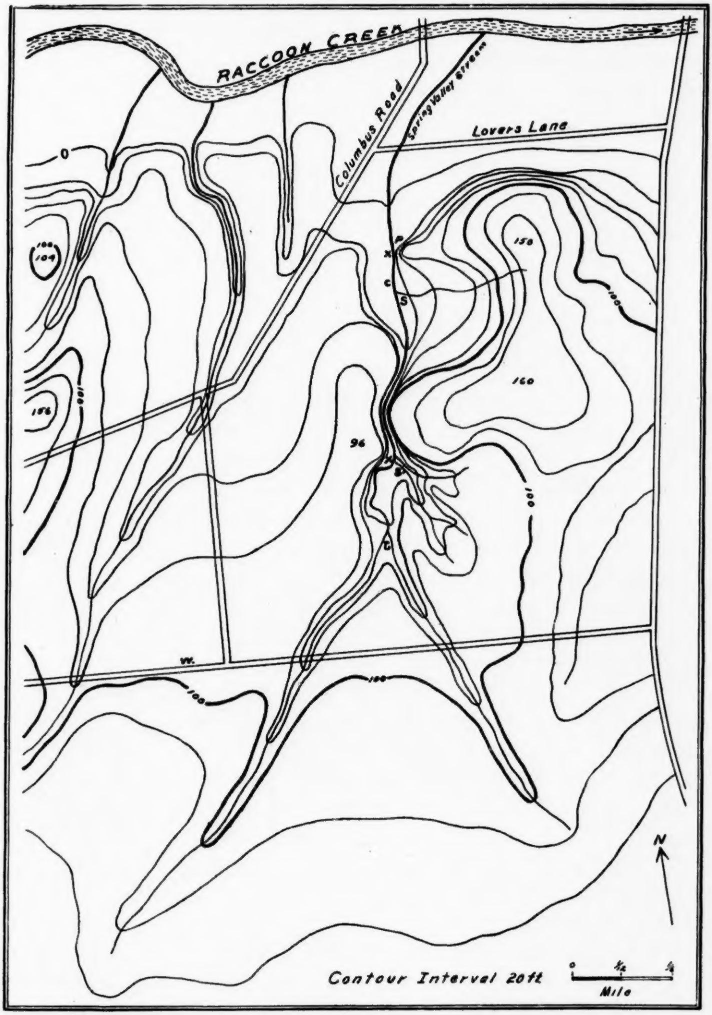

Fig. 1. Contour map of the Old Valley. *X-X* marks the limits of Spring Valley. *S* and *S'* are captured streams now tributary to Spring Valley stream. *J*—The junction of two streams forming Spring Valley stream. *C*—Cut of this stream across the old pre-glacial channel of the tributary *S*. *W*—145 ft. well. *P*—At this point the Spring Valley stream is flowing on rock, between a rock wall on the east, and a wall of glacial debris across the flood plain on the west.

the Old Valley referred to above, which includes within its boundaries nearly all the data given.

THE OLD VALLEY.[1]

That the Old Valley is of pre-glacial origin is obvious. If the walls were of glacial debris, a post-glacial theory might obtain; but while the floor is covered with a heavy glacial deposit, rock of the Black Hand formation outcrops in corresponding horizons near the Raccoon ends of the east and west walls, and also at points on the western side near the valley head. It is equally clear that originally the valley was deeper than at present, as it has been partially filled with drift.[2] Its situation was particularly favorable for such accumulation. Overridden by ice, as shown by glacial accumulations on the highest parts of its walls, the situation with respect to glacial-motion (from the north and northwest) was particularly favorable for holding a mass of ice as in a pocket, retarding onward progress, and admitting continuous accessions to take the place of the ice melted.

That such a process continued during a long period of time, and very effectively from a depositional standpoint, is evidenced by the great depth of debris in the valley. Data for many portions was not available. Among such portions may be included the valley divide on its eastern wall and also the southern end of this wall which present peculiar phases suggestive of old and new drainage complications, a discussion of which would not be relevant to this article. Above the exposed rock walls a thin deposit of drift varying in depth in accordance with simple topographic laws is found. At the point marked W on Fig. 1, where a 145 foot well was drilled two years ago, 136 feet of drift was penetrated before rock was reached. The point mentioned is but a short distance from the valley wall where rock outcrops in a drainage bed, with only about 15 ft. of debris above it. This would indicate a far greater thickness of deposit in the lower part of the valley course. None of the wells in this section about which information was obtained are as deep as the one above mentioned, nor do they reach the rock, but a gas well drilled in the flood plain

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[1] Leverett, U. S. Monograph XLI (1902), p. 172.

[2] Wright refers to drift about Granville in his "The Ice Age in North America" (1891), pp. 468, 493. Cut on p. 284.

of Raccoon Valley at a point about one-half mile east of Spring Valley struck rock 275 ft. below the surface, a depth quite likely approximating the greatest thickness of aggraded material (some of which, however, may represent the pre-glacial flood plain), in the tributary "Old Valley."

Spring Valley, then, can not be explained as coincident in origin with the development of the Old Valley, for such an explanation would present the incongruity of two parallel streams, one flowing near the axis of the valley, with normal tributaries, the other elevated possibly over two hundred feet flowing laterally along the eastern side in a rock gorge. If any possibilties of structural weakness or of topography could even permit the formation or origin of such a stream, its course would not be maintained for any long period of time. Soon a vulnerable point in the relatively narrow west bank separating it from the old valley would be discovered, and the waters released to take a natural course tributary to the stream occupying the axis of the Old Valley.

Before dismissing the topic "The Old Valley" it may be remarked that a theory of glacial origin due to erosional processes of glacial ice is not tenable. The thickness of debris in this section and its low percentage of local constituents suggest the erosional-inactivity of the enclosed ice during at least the later stages of the Ice Age, while protecting hills of rock in height about the same as the walls of the Old Valley, lying on the farther side of Raccoon Valley and opposite to the entrance of the Old Valley into the latter, as well as the trend of this valley transverse to ice-movement, offer irreconcilable difficulties to any theory of active erosional processes in this section during any glacial epoch.

Also the topography of the valley, its great width relative to its length, and the great depth to bed rock, is indicative of an earlier drainage line, a line continuing during such a long interval of time that this area was probably reduced to a mature condition with erosional processes declining in a rapidly changing ratio as cutting proceeded. At the period of its history just before glaciation this Old Valley may be regarded as having about as nearly approximated a condition of base-level as its distance from the sea would permit.[1] This evidence of maturity in the Old Valley

[1] Davis, "Base Level, Grade and Peneplain," Journal of Geology, Vol. 10 (1902), pp. 77-111.

Fig. 2. View looking across the Old Valley toward the east. Note the continuous upward slope of the east wall, almost concealing Spring Valley lying between X-X. The mature appearance of the Old Valley, with the cut of the central drainage line through unconsolidated material is shown.

may be also urged against any theory of inter-glacial origin.

The present drainage lines of the Old Valley, with the exception of Spring Valley, offer little of interest following as they do subsequent courses over the drift.

In connection with this discussion of the Old Valley, it may be mentioned that there is evidence of a west-flowing pre-glacial stream in the valley of the Raccoon (to which this Old Valley is tributary). The cause for the diversion of Raccoon Creek at this point from a west-flowing to an east-flowing stream will be the subject of a future paper.

SPRING VALLEY STREAM.[2]

Spring Valley Stream is formed by the union of two slight creeks, converging and draining the entire southerly portion of the Old Valley. These two streamlets, starting on the valley walls, follow lines through the drift, and present no peculiar drainage features until a short distance beyond their junction (J. Fig. 1), where a sharp bend eastward then a northward turn leads the united stream through a gorge cut into the eastern wall of the Old Valley. This portion of its course is known as Spring Valley. Both data and theory will be given to show that Spring Valley

[2] See reference under the Old Valley.

can be neither of pre-, inter-, nor post-glacial origin, but must be of late glacial development.

One step of the proof that Spring Valley is not of pre-glacial origin has already been given in connection with the discussion of the Old Valley, but the most striking evidence against such a theory is found along the course of Spring Valley itself. Its rock walls rise almost perpendicular. Above them the banks reach still higher, particularly on the eastern side, over a gentle debris-laden slope. The effect is such that viewing the east wall of the Old Valley, as in Fig. 2, a continuous even slope almost concealing Spring Valley (between the points *X* and *X*) is observed. Such a continuity of slope could not obtain if the stream were of pre-glacial origin for if, as stated above, such a stream were once formed it would soon cut through its western bank at some point and drain into the major stream.

Only abnormal conditions, as might operate during a glacial epoch, could originate such a course. The divergence of the united stream from debris into a rock channel on the valley wall, when the course could far more readily be continued under normal conditions through drift to the axis of the major valley, can not be consistently explained on any other hypothesis.

The steep rock walls of Spring Valley are evidence of newness. The gentler slopes above them, debris-covered, indicating a well eroded surface sloping to the axis of the old valley, contrast sharply with these but slightly weathered almost vertical rock walls. The slope of the stream bed is also an indication of comparative newness. The fall through Spring Valley alone, a distance less than one-third of a mile, is 35 feet.

The most striking proof of the late origin of Spring Valley is found in its tributaries. It is obvious from the description of this valley already given that all secondary drainage must be received from the eastern side. This tributary drainage is represented by the stream S, Fig. 1, in the lower part of its course, and by the two streams, which for reasons to be explained later may be regarded as one, marked S′, Fig. 1 and Fig. 3, in the upper part of its course.

The first of these tributaries, a tiny stream draining a small area, occupies a short valley showing every evidence of maturity.

No rock walls are exposed and the slope from the valley top is uniformly gentle to the stream bed, which is an insignificant cut in glacial debris. Presumably this valley at one time contained much more debris than at present, but this unconsolidated material has permitted rapid erosion, lowering the stream to the grade of Spring Valley, and developing a valley similar to the original in its upward slopes. One essential difference, however, is noted: At the junction of this valley with Spring Valley in a cut (*C*, Fig. 1) through the flood plain which the latter has built across the present mouth of the former is exposed compactly bedded deposits of blue and yellow clay-like material, located in what would naturally be the bed of this tributary stream; in places these deposits are nearly homogeneous, showing little evidence of foreign gravels. Again, especially in some of the yellowish or brown colored sections, ample evidence is found of foreign pebbles.

At a point (*P*, Fig. 1) just north of this tributary to Spring Valley, in the cut of the latter, the east rock wall abutting Spring Valley and the rock bed of its stream is noted. Proceeding southward the rock wall gradually declines forming the even north slope of the tributary valley. For a short distance further the rock shows but a few feet vertical exposure in the cut of Spring Valley flood plain. Then the outcrop becomes more and more

Fig. 3. View from flood plain of Spring Valley stream, looking north. *S'*—Captured drainage now tributary to Spring Valley stream. *X*—Entrance to Spring Valley gorge. Rock outcrop shows to the left.

broken, finally blending into the clay-like material previously mentioned. This material, with some modifications, continues until near a point opposite the south bank of the tributary valley *when a progressive change to solid rock walls and bottom is noted* as first instanced. In general a consistent arrangement of materials is observed on both banks of the cut in this flood plain.

Only one explanation for this peculiar arrangement of debris in the mouth of this tributary to Spring Valley seems plausible. It is readily accounted for on the hypothesis that this drainage line formerly crossed what is now Spring Valley, emptying into the stream of the Old Valley. During glacial times this channel was filled with drift, part of which is now revealed as before mentioned. That a flood plain has been formed by the Spring Valley stream at this point and on both sides (the area surrounding *C*, Fig. 1) is due to the comparatively soft material constituting the debris filling the old channel (tributary to the Old Valley) which it has been able to cut out rapidly at an earlier period of its history. Thus for a part of its course this old valley was exposed, while its drainage was captured at the same time.

In this connection it may be noted that there is no high rock wall corresponding on the west side to *P*, Fig. 1, on the right side. Instead the bank shown is of glacial debris deposited over the old channel of the captured tributary S. This tributary in its original course to the axis of the Old Valley cut off what would otherwise have been the northern end of the western rock bank of Spring Valley.

The Old Valley and this tributary *S* doubtless were long under the influence of glaciation. The immense depth of debris in the former would alone indicate this, but in the tributary S, particularly in the cut through this old filled channel, as stated above, evidence is found of the varying age of the drift. Some of this material, as before described, is clay-like, yellowish in color indicative of a long period of exposure and resultant weathering, probably during an inter-glacial epoch. A blue clay also frequently outcrops. It is difficult to determine in this limited exposure the relative positions of these clays. The blue clay horizon, however, seems to be below the yellow, hence is suggestive of an earlier protected deposit. The appearance of these clays corre-

sponds to Leverett's description of the Illinoian drift[1]. At several points in the cut a thin bedding of foreign pebbles cemented into a conglomerate like mass was noted. The stained and weather-worn appearance of these masses suggests great antiquity.

The compactness of all the drift lying below the recent deposit of the Spring Valley flood plain at the point mentioned implies great pressure, due probably to overlying debris which has been removed, and the weight of the over-riding ice. Many large granite bowlders are also noted at this point and southward, the presence of which will be discussed later.

The history for the second tributary streams S' is similar to that for S, but the explanation is more complicated. The more northerly of the two small streams runs over rock near its junction with the Spring Valley stream, and shows rock walls extending about one foot vertical height on either side. But on the north side alone can be traced the gradual rise of rock along Spring Valley, representing probably the old north wall for this second pre-glacial stream now tributary. Drift alone is found for some distance south of this point, the other and smaller stream showing no evidence of rock exposure. Presumably the first stream is pursuing a course lying just at the base of the north rock wall of this second valley tributary to Spring Valley. The south rock wall has not been definitely located. It is hence evident that these two streams have their rise in a drift-filled channel tributary to the Old Valley, as in the case of the stream S. The debris-evidence in the cut of Spring Valley stream through its flood plain at this point before entering the gorge, confirms this theory.

It may be added that the flood plain material directly above the rock at the points between the two tributary valleys just discussed, and imposed on the clay-like debris marking the old preglacial channels of these tributaries, is itself evidence of the comparatively recent origin of Spring Valley. This flood plain material is composed of stratified layers of broken local sedimentary rock mingled with glacial debris, the former generally in excess.

THEORIES FOR ORIGIN OF SPRING VALLEY.

This article has endeavored to show that Spring Valley does

[1] Leverett, U. S. Monograph XLI, p. 272.

not mark a pre-glacial drainage line. The other possible time periods of origin are inter-glacial, post-glacial and glacial.

Inter-glacial Theory. The arguments for an inter-glacial theory of origin must be similar to those amplified in the succeeding paragraph. The same objections also hold. This theory has an even less secure basis, for admitting that such a stream might be formed inter-glacially, later glacial epochs would probably obliterate its channel with debris.

Post-glacial Theories. On the supposition that the Old Valley was formerly filled high up on its walls with glacial debris, it might be concluded that the Spring Valley drainage formerly pursued a consequent course superimposed over solid rock, in glacial debris; soon cutting through this drift into the rock, its course became fixed. Then the western portion of the Old Valley with its greater depth of glacial rubbish, permitting more rapid cutting than did the rock bound Spring Valley, has been given its present topography as hitherto described, leaving Spring Valley following laterally on the east valley wall. This theory is hardly tenable since a mature transverse valley is rarely so completely buried that its topography is not a factor in post-glacial time. The drift would tend to slope downward to the axis of the original valley, and drainage lines originated on the drift-covered valley wall would normally tend toward this axis, rather than cut a channel through solid rock parallel to it.

One theory for the origin of rock gorges in Licking County is that they have been formed by the undermining of the rock by springs, the action being accelerated by the caving in of the rock roof from time to time.[1] Such an explanation does not adequately account for the great depth (Fig. 1) and the width of Spring Valley gorge, especially considered with reference to its appearance of newness as elsewhere described. Neither does it account for the large number of granite bowlders found along this valley, which must, according to such an explanation, have come from an area above but little larger than that of the present valley. The eastern slope of the old valley does not carry many bowlders. This theory, moreover, would demand that the lower

[1] M. C. Read, "Licking County," Geological Survey of Ohio, Vol. III, Part 1, (1878), pp. 350, 351.

part of the rock be the most weathered, a reversal of what is found in normal streams. Spring Valley gorge corresponds with the latter in this respect.

Glacial Theories. Early Glacial.—That such a gorge as that of Spring Valley might have been formed during early glacial times would be quite in accordance with the accepted explanation given later. The difference, however, is apparent. It is not probable that the ice would maintain a stable position relative to this channel throughout a long interval of time. There would be many advances, retreats and halts. Its chance for survival during such changes in the ice movement would be the same as for any deep depression. It would be filled with debris and smoothed to correspond with the adjacent topography.

Sub-glacial Theory.—That sub-glacial streams are of frequent occurrence is a fact well known to the literature. That such streams frequently follow courses independent of topography is equally well known. Such streams, however, are usually overladen with debris received directly from the ice. This, together with the restraint of the ice-covering reduces their cutting efficiency, sometimes even making them so inactive that deposition rather than erosion obtains. In Spring Valley an erosional activity is evidenced with few parallels in known sub-glacial stream courses. Further argument against this theory is similar to that in the preceding paragraph. Even if formed under such conditions as mentioned, the instability of the ice would tend to change the channel, as well as to fill any channels that might be formed with glacial debris. However favorable the conditions, none of these channels could escape the influence of the ice-retreat.

Late-Glacial Theory.—While it is impossible to prove without question such a genesis, nevertheless in the theory of a late-glacial origin of Spring Valley it is difficult, if not impossible, to find unanswerable objections to any of its phases.

During this period the Old Valley can be imagined as occupied by ice reaching out over the west, abutting against its east wall and extending as a tongue for some distance along the valley of the Raccoon, the ratio between advance and retreat at this time approximating unity. Under such conditions the ice would melt away from its upper contact with the east wall of the

Old Valley on both the west and north exposures, leaving a channel between the rock and ice. This channel would afford a ready outlet for ice-front waters, and with the ice maintaining a permanent position, the gorge cutting would proceed rapidly. After a certain period of time, a period determinable by the volume of glacial waters and its cutting tools, a channel would be developed which, by incising the solid rock of the valley wall, might become fixed for an indefinite period.

The large number of big granite bowlders found, especially near the outlet end of the Spring Valley course, is indicative of the vigor of this late glacial drainage. This circumstance also supports the theory, later elaborated, that Spring Valley drainage, while the ice maintained its position in Raccoon Valley, took a course eastward around the north end of the Old Valley wall; the lowering in the velocity of the water near the turn would cause the heavier part of its load to be dropped.

The stratigraphy of the Black Hand rock also favors the late-glacial theory; of sandy shale-like character, with numerous joints and bedding planes [1] both normal weathering and the removal of large blocks of stone would be facilitated.[2]

While on the western slope of the east wall of the Old Valley the waters soon cut a channel into the rock so far that a guarding boundary of ice was no longer essential, it is probable that towards the northern end the ice constituted one bank of the stream for a longer period of time. Here the conditions differed, the stream channel, being parallel to the direction of ice movement in the Raccoon Valley, could maintain its position even while the ice tongue was retreating.

The theory that this drainage line after emerging from Spring Valley continued its course around the end of the valley wall as before suggested constitutes in itself a problem. There are several facts in accord with such an explanation. The steepness of this slope indicates but little weathering. If this steep condition had been produced pre-glacially it would present a more mature appearance, and if eroded by ice the tendency would have been to accentuate such a condition. There is, moreover, practically

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[1] Carney, "Geology of Perry Township, Licking County, O." Bulletins Scientific Laboratories, Denison University, Vol. XIII (1906), p. 120, 123.

[2] Westgate, "Abrasion by Glaciers, Rivers and Waves," Journal of Geology, Vol. XV (1907), pp. 116, 117.

no glacial debris on this end. Its absence can readily be explained by the presence of such a stream which, turning the bend eastward on emerging from Spring Valley, would first be checked in its speed, leaving a large part of its load behind, then with renewed force would sweep along between the northern end of the east valley wall and the ice, clearing from the former any debris which may have been laid before the genesis of this stream.

Part of this debris would be carried forward with the stream, part dropped to its bottom, this process continuing as the stream lowered itself between the rock wall and the ice. As the Raccoon ice tongue retreated back of this valley end, this stream would be finally released so that a normal route could be followed from Spring Valley to the drainage line of Raccoon Valley. Any terrace left would be rapidly obliterated by weathering and erosion, though even now the lower slope of this end wall is suggestive of a former stream terrace.

SUMMARY.

A. That the Spring Valley stream is not of pre-glacial origin is proved by

1. Its position on the east rock wall of the Old Valley, following a lateral course parallel to the axis of this Old Valley.
2. The fact that its tributaries formerly emptied into the drainage line of the Old Valley.
3. The character of its rock walls and of the glacial debris found along its course.

B. That Spring Valley is of late glacial origin, having started between the margin of the ice and the valley wall, is supported by

1. The elimination as not plausible of a pre-, post-, and early glacial genesis.
2. By the strict accordance of this theory with the possibilities.

C. Theory and data suggest that the Spring Valley stream continued around the north end of the east wall of the Old Valley between ice and rock until the retreat of the Raccoon ice-tongue.

Geological Department, Denison University, Granville, Ohio, July, 1907.